Volume XVIII] *January, 1913* [*Number 2*

The

American Historical Review

CHANGES OF CLIMATE AND HISTORY

IT is not by accident that the most universal subject of conversation is the weather. The New Englander says hard things of the east wind, the Chinese patiently wonders when the first rains will fall in the spring and start the growth of the seed that he has planted, and the Arab who meets a stranger inquires where rain has fallen. So, too, the Egyptian talks of the rise of the Nile, and probably the Eskimo converses with his friends about the terrible heat when the thermometer rises above freezing for several days. All these things are merely the expression of the fact that among the phenomena of nature none affect mankind so directly and vitally as those which pertain to climate. If man is so deeply influenced by the climatic conditions which now prevail, it is manifest that any changes of climate which have taken place in the past or may take place in the future are of the highest importance. The realization of this fact has led historians, geographers, and others to discuss the question of changes of climate ever since the days of the Greeks. Plato and other writers say that formerly the climate of Greece was moister and the forests more abundant than in their day. Aristotle declares that the flood of Deukalion was due to a periodical cycle in atmospheric phenomena. He states that just as winter returns regularly each year, so great cold and heavy precipitation return in the course of long periods. In other words he announces the theory of pulsatory changes of climate. For two thousand years that theory lay in abeyance. Many people discussed the possibility of a gradual drying up of the earth, a gradual cooling off, or a gradual increase in warmth, but all the discussions were based on the idea of slow and comparatively regular changes. It was left to the present writer to propose the theory of pulsatory changes once more, quite uncon-

scious that in so doing he was following in the steps of the Greeks.[1]

The modern historian realizes the importance of physical factors, especially of climate, in influencing some of the great facts of history, but he does not usually admit more than a slow and general effect as opposed to the rapid and marked effects which the adoption of the theory of pulsatory changes would naturally demand. This attitude is well illustrated in a recent article in the *Journal of Geography,* by Professor A. T. Olmstead of the University of Missouri.[2] Speaking of the relation of climate to the people of a country, he says:

> It has long been recognized that it has important effects upon the inhabitants, but also that the most important effects result only when those inhabitants have long occupied the country. Egypt affords an excellent example of the value of climatic study in this connection and also of its dangers if not used in the light of history. Here we have a hot, dry climate where the main dependence for the crops is not on the rains but on the rise of the Nile. This rise, regular as the seasons, the comparatively small change in temperature among the seasons themselves, the almost complete absence of rainfall, taken in connection with the fertility of the soil and the small number of staple crops, has produced a condition of affairs in which all that is demanded is a steady carrying out of a routine which never changes and requires rather brawn than brain. This we find admirably reflected in the character of the peasantry, now, as in antiquity, interested only in the securing of enough food to live and to marry upon. But this did not seriously modify the character of the ruling class for, from pre-dynastic times, they have always been foreigners. Accordingly, their character has always been that formed in other countries. Only one effect should be noted. Just because they did not adjust themselves to the climate, they became enervated and finally were killed off. In other words, the climate had only a negative effect on the men who have made Egyptian culture worthy of our study. And, since history means evolution, the unchanging peasantry, who show most strikingly the effect of climate, need be mentioned once only by the historian, after which their existence may be assumed for the further historical relation.

If, for the moment, it be granted that all the important contributions of Egypt to human history have been due to invaders, and that the peasantry have from time immemorial preserved exactly the same character, the historian and the geographer agree just as

[1] The first full statement of the theory appeared in *The Pulse of Asia* (Houghton Mifflin Company, 1907). It has since been amplified in *Palestine and its Transformation* (Houghton Mifflin Company, 1911), and in several magazine articles, especially "The Burial of Olympia", *Geographical Journal,* XXXVI. 657–686 (1910), and "Physical Environment as a Factor in the Present Condition of Turkey", *Journal of Race Development,* I. 460–481 (1910–1911). A cognate subject is treated in an article entitled "Geographical Environment and Japanese Character", *Journal of Race Development,* II. 256–281 (1911–1912).

[2] A. T. Olmstead, "Climate and History", *Journal of Geography,* X. 163–168 (1912).

far as the historian goes. They part company, however, when it comes to the question of why the invaders came into Egypt and were thus given the necessary wealth, leisure, and other opportunities which enabled them to develop their talents and become great. The geographer who believes in pulsatory changes of climate can scarcely avoid the conclusion that great movements of peoples have been induced by such changes, and that these movements have given rise to periods of invasion and anarchy. Furthermore, he is led to conclude that when the stress due to unfavorable climatic conditions has been removed by reason of another change, this time in the direction of more favorable climatic conditions, prosperity and progress have been the rule. This by no means implies that all invasions and all prosperity are supposed to be due to climatic causes, but merely that climate has been one of the important factors in producing such results. I do not propose to discuss this question here, as I have already considered it in the publications referred to above, especially in the later chapters of *The Pulse of Asia* and *Palestine and its Transformation*. I wish, however, to concentrate attention upon the question which, at the present stage of investigations, is the crux of the whole matter. If Professor Olmstead is a fair representative of the younger school of modern historians, the views of that school would coincide with those of the geographers, provided there were certainty upon one point, namely, the verity of our conclusions as to climatic pulsations. After devoting some pages to a statement of reasons for not believing that such pulsations have taken place, Professor Olmstead concludes:

> We have not the space to further test by historical facts the theory that the Arabian desert with its surrounding lands [was once] more occupied, more fertile, and easier of access than it is at the present day. Further examples would only prove that it was not well grounded. And this brings us to our conclusion as regards the question of the relation of climate to history. That climate, working through the ages, has a highly important effect on the permanent population of a country is admitted by every historian. That it has effects, mostly negative, on the transient population has also been seen. At present, the theory of a more immediate influence on the details of history seems to be bound up with the theory of cyclic [pulsatory] climate changes and we have seen that the facts of history tend to disprove this. Accordingly, the historian is not justified in utilizing climate for more than the study of the background of his history. For influence on particular events, there are many geographical facts of far more significance.

The question before us divides itself into two parts. In the first place, was the climate of the past, let us say at the time of Christ, different from that of the present? In the second place,

assuming that there has been a change, did it take place gradually or was it characterized by pulsations whereby certain periods were exceptionally dry while others were moist? The type of evidence to be employed is the same in both cases, and consists first of physiographic phenomena among which river terraces, lake strands, denuded mountain slopes, desiccated springs, and rivers whose salinity has increased, are of special importance. A second highly important type of evidence consists of archaeological phenomena, such as the location of ruins like those of Palmyra or Ilandarin. Here, in the past, great cities grew up in places whose supply of water is now not one-tenth large enough for the support of such a population as once existed. Still a third line of evidence is based upon plant life, forests, areas of cultivation where crops cannot now be grown, and the like. Finally, with all this must be joined direct historic evidence, such as accounts of famines, recorded facts as to the supply of water in places now dry, old roads across deserts which to-day are impassable, and a vast number of other matters which have never been properly scrutinized because historians have not investigated the subject.

In all these cases it is far easier to find and interpret evidence in reference to the first of our questions than to the second; for the discovery that regions which once were well populated are now uninhabitable is a comparatively simple matter, while only the most careful research reveals the reasons for believing that while the past as a whole was distinctly moister than the present, certain periods were notably drier. This would seem to indicate that if some new method of investigation is to be tried, the study of possible fluctuations is more important than that of possible differences between the past and the present. If the fluctuations should prove to have taken place as inferred from the other lines of evidence, there would be little question that the climate of the past, as inferred from those same lines of evidence, was in general different from that of the present. Hence in this article I wish to present a new type of evidence which seems to go far toward proving conclusively that the pulsatory theory of climatic changes is correct. By this I do not mean to imply that all the details of the climatic curves which are shortly to be presented are as yet established beyond question. I merely mean that the evidence seems to indicate that pulsations of climate lasting through periods having a length of centuries have actually taken place. This, it will be seen, is in direct opposition to the statement of Professor Olmstead. "At present", to repeat a sentence already quoted, "the theory of a more immedi-

ate influence on the details of history seems to be bound up with the theory of cyclic [pulsatory] climate changes and we have seen that the facts of history tend to disprove this."

The question cannot be settled offhand by a reference to "the facts of history". Long research in the realms of physiography, climatology, archaeology, and, as I shall shortly point out, botany, can alone determine it. In other words the problem is primarily geographical, in the modern sense of that term, and the final decision of geographers must be accepted by historians. When it comes to the study of the effect of any possible climatic changes upon the course of history, however, the case is reversed; the geographer may offer suggestions, but the final decision rests with the historian. Hence the purpose of this article is to show the grounds upon which an increasing number of geographers are becoming convinced that changes of climate have actually taken place, and then to suggest certain ways in which these changes may have been of historic importance. I realize fully that in making these suggestions a geographer is liable to error, for his view of history must of necessity be limited. Therefore in no case would I be understood as asserting categorically that such and such results have occurred because of climatic changes, but merely that certain results appear probable from the point of view of the geographer. If the changes here discussed have actually taken place, they must have had some effect upon history, and it is only by discussion of the question from both the historical and geographical sides that the truth can be learned.

Lack of space forbids any discussion of the evidence of changes of climate in Asia, and I must once more refer the reader to *The Pulse of Asia* and the other publications already named for a statement of the results of three expeditions to Asia during which about three years were spent in the Turkish Empire, Persia, India, the southern portion of Asiatic Russia, and the western part of China. These expeditions, extending over the period from 1903 to 1909, led me to formulate the theory of pulsatory climatic changes. The evidence which was first found indicated only the greatest pulsations, but as time went on the number was seen to be larger, or rather the details of minor pulsations became more clear. At best, however, the resultant climatic curve was no more than an approximation to the truth. Some definite, mathematical method of measuring rainfall or other climatic factors was necessary. In order to test the theory as widely as possible I accepted the invitation of Dr. D. T. MacDougal of the Department of Botanical Research of the Carnegie Institution of Washington to co-operate with the Desert

Botanical Laboratory at Tucson, Arizona, in a study of the climate of the arid portions of the United States. Two seasons of field work among the dry lakes, terraced valleys, and innumerable ruins of Arizona, New Mexico, and the neighboring parts of Mexico, supplemented by a journey to southern Mexico and Yucatan, led to the conclusion that the climate of America has been subject to pulsations similar to those which appear to have taken place in Asia. I have discussed the matter in articles appearing in *Harper's Magazine* during the years 1911 and 1912, and in a series of articles in the *Geographical Journal* of London, and shall not here attempt to say more about it. The lines of evidence were similar to those followed in Asia and Greece, that is, they were primarily physiographic and archaeological, with the addition of historic evidence wherever possible. They will be fully discussed in a volume shortly to be published by the Carnegie Institution of Washington under the title, "The Climatic Factor".

Leaving, now, these more purely geographical lines of research, let us turn to another type of evidence which seems to add to the conclusions already reached the final touch of mathematical accuracy which alone can lead to certainty. Realizing that my work in America was liable to error because of the danger of being influenced by a preconceived theory, I made use of a method suggested by Professor A. E. Douglass of the University of Arizona.[3] Professor Douglass found that the thickness of the rings of annual growth in the old trees of the forests on the plateaus of Arizona is proportional to the amount of rainfall. If the average growth in diameter of a large number of trees be plotted for year after year, the ups and downs of the curve thus formed agree in general with the ups and downs of the curve of annual rainfall plotted in the same way.

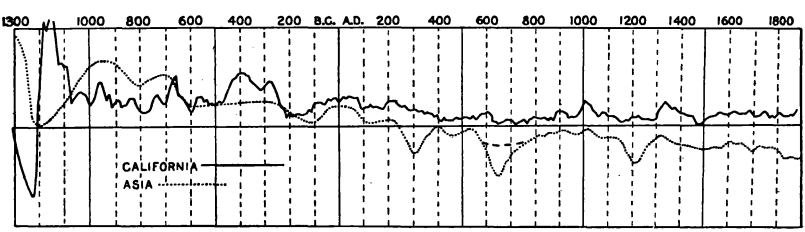
Evidently, then, the annual rings of old trees preserve a record of the rainfall in past times, and it is only necessary to read this record to answer the question of the reality of climatic pulsations extending over hundreds of years. Before great accuracy can be obtained it is necessary to eliminate the effects of variations in the growth of trees because of differences in age. Young trees grow faster than old, but there is a regular law for this, as is well known to foresters, and it is purely a matter of mathematics to apply the necessary corrections. Accidents such as fires or storms also affect the rate of growth, but, as I have shown in the articles already mentioned and in another which will soon be published in the *American Journal of Science,* these become negligible when a large

[3] A. E. Douglass, "Weather Cycles in the Growth of Big Trees", *Weather Review,* XXXVII. 225–237 (1909).

number of trees from different localities are employed. Thus, after all corrections and allowances have been made, we are able to secure a curve which represents with considerable accuracy the fluctuations of climate in past times. The process by which this is obtained is purely mathematical, and no amount of theorizing on the part of the investigator can affect the results.

During the years of 1911 and 1912 I measured the rings of four hundred and fifty of the Big Trees, or *sequoia gigantea,* of California, which, fortunately for the purposes of historical research, had been cut in order to make fence posts and shingles. These trees grow in the Sierra Nevada Mountains under climatic conditions closely similar to those of the high plateaus of Arizona. The winter is snowy and rain falls during the spring until May or June, but the rest of the summer is absolutely dry. The forests need more rain than they commonly get. In years when the amount of winter snow is larger than normal, or when the storms of spring persist well into the summer, the trees grow much faster than usual. The trees which I measured ranged from 230 to 3200 years of age. Eighty began to grow more than two thousand years ago, and three were more than three thousand years of age.

From these four hundred and fifty trees I have constructed the curve shown by the solid line in the accompanying diagram. The



course of time is represented by horizontal distance, the left end indicating the date 1300 B. C., and the right end 1900 A. D. High portions of the curve denote moist conditions, which would be highly favorable in countries like Syria, Egypt, and Greece, but detrimental in such countries as Germany or England. Low places, on the contrary, indicate relative aridity, which would be disastrous in lands such as Palestine. The details of the curve will be modified somewhat when a larger body of data is available. For instance the violent zigzags of the earlier portions, where the number of trees is small, will undoubtedly be reduced. The general form of the curve, however, will in all probability remain as here indicated, although previous to about 200 B. C. the fluctuations will be less sharp and the extremes of the peaks and depressions will not rise so high nor fall so low as is here indicated.

No matter in what minor respects the curve may be changed by further investigation, one feature can scarcely be eradicated, namely the sinuosity. It appears impossible to interpret this in any way except as conclusive evidence of pulsations of climate extending over hundreds of years. Omitting the earlier and less certain parts of the curve, we see that at the time of Christ the average *sequoia* tree grew at least thirty per cent. faster than in 1500 A. D. This does not mean that the rainfall was exactly thirty per cent. greater. It may have been twice as great, but as to that we cannot yet speak with any certainty. Thus much, however, seems evident: if the huge *sequoia* trees high among the relatively moist mountains fell off thirty per cent. in their average growth in spite of their favorable position and vast root systems, smaller vegetation must have diminished to several times as great an extent. Moreover we are not dealing here with individual years, but with decades, which would appear to mean that individual years must have shown much greater extremes than those indicated in the curve. We infer then that during the last three thousand years not only has the climate in general become drier as indicated by the general trend of the curve, but that it has been characterized by pulsations lasting hundreds of years and by variations in rainfall sufficient at least to halve or double the productivity of the land.

Thus far we have been dealing with California, but our results appear to apply to Asia and Europe with equal force. For the sake of comparison I have added to the diagram a dotted line. This represents the condition of the curve of climatic pulsations in Asia so far as I had been able to obtain data up to 1910, the time of writing *Palestine and its Transformation,* from which volume (pages 327 and 403) the curve is reproduced. Since then a few further facts have been noted which would tend to modify the curve somewhat. As time goes on there can be no doubt that further modifications of considerable importance will be necessary. It must be borne in mind that this curve is a pioneer attempt at the elucidation of an extremely complex subject. At the very best it merely bears the same relation to the ultimate truth that the history of Babylonia and Assyria as written by Rawlinson bears to the history of those same countries as written in the light of the most recent excavations.

In spite, however, of the avowedly tentative nature of the Asiatic curve, it agrees to a notable degree with that of the trees of California. To be sure there are certain marked disagreements. These may be due to actual differences between the changes in California and Asia, or to an absence of data in compiling the Asiatic curve.

Among meteorologists and climatologists there is a growing conviction that a change of climate in one part of the world is synchronous with that in another. As Ward puts it in his authoritative work on *Climate,* "It is now believed that oscillations of climate are limited in time, but occur over wide areas."[4] Therefore the presumption is that further knowledge of the climate of Asia will cause the curve for that portion of the world to be modified until it approximates to that of California. Nevertheless differences in latitude may cause a given climatic change to assume different aspects according to the zone of winds with which we are dealing; and there is some reason to think that oceanic areas are subject to changes more or less contrary to those of continents. The Californian curve comes from a small continental or interior region between 36° and 37° north of the equator. The Asiatic curve, on the other hand, is based on data from diverse continental regions located from 30° to 42° north of the equator, and is therefore more liable to error than is the other.

The degree of difficulty experienced in preparing the Asiatic curve may be judged from the fact that the line is straight between 1200 and 1000 B. C. simply because between those dates I have as yet been able to find no facts bearing directly upon the climatic conditions. Further data might have caused the curve to be sinuous in harmony with the American curve. In other cases the fact that marked evidences of aridity were noticeable at a particular time or happened to be recorded by man or nature with especial clearness may have led me to carry the Asiatic curve lower than was justifiable. For instance a marked degree of depopulation, an uncommonly low level of enclosed lakes, traditions of famine, and other evidences appear to indicate that the seventh century of our era was an exceptionally dry time, but there is absolutely no available evidence as to the exact time when the dryness culminated, nor as to how dry that particular century was as compared with others. A curve drawn as indicated by the dashes would have fitted the facts equally well. Even as the curves now stand, however, the longest continuous decline in the Californian curve culminates at the middle of the seventh century at about the time when the Asiatic curve is lowest. Another case of almost exactly the same kind is found in the thirteenth century. There are pronounced evidences of aridity in Asia at the end of the twelfth century and in the first half of the thirteenth. Therefore the curve dips very low, and the minimum point is placed during the first part of the thirteenth century. The next available evidence indicates favorable conditions in the first

[4] R. DeC. Ward, *Climate considered especially in Relation to Man,* p. 363 (New York, 1908).

part of the fourteenth century. In the absence of any knowledge as to the latter half of the thirteenth century, the curve was originally drawn as shown in the dotted line. The Californian curve, however, fits the facts quite as well, and probably indicates the true state of affairs not only in America, but in the same latitudes in the eastern hemisphere. Similar reasoning applies to the low portion of the curve found at 300 A. D. At about that time a large number of ruins were abandoned in places which are now waterless, and other types of evidence also suggest aridity. Nevertheless it is probable that this and, to a less extent, the other main depressions of the Asiatic curve are exaggerated because special events happened to culminate at those particular times.

In spite of certain differences the high degree of agreement between these two curves from parts of the world as remote as western Asia and California is remarkable. Take the epoch centring at the time of Christ, for example, or those which centre at 1000 A. D. and 1600 A. D. The agreement is so close that it cannot be a matter of chance. This is the point which needs especial emphasis. We have here two curves based on entirely diverse kinds of evidence from parts of the world six thousand or more miles apart. One of the curves is based on lines of evidence which are at best highly fragmentary, and into which the element of personal interpretation enters largely. The other is based on a line of evidence which is absolutely continuous for two or three thousand years, and into which the element of personal judgment enters not at all. The two curves agree as to their main features, and in some cases the agreement extends to small details. The only satisfactory explanation of this result seems to be, first, that the climate of many portions of the past was different from that of the present; secondly, that climatic pulsations having a periodicity of centuries have been the rule; and thirdly, that these pulsations have been essentially synchronous in the eastern and western hemispheres.

If these conclusions be granted, it at once becomes evident that the climatic pulsations must be taken into account in the interpretation of history. How important they are, however, cannot now be determined. To the geographer and especially to one who has devoted years to this particular line of study, they probably appear more important than they really are. Therefore I speak with diffidence, and only in the hope that duly qualified historians may find the matter of sufficient interest to warrant its independent investigation on their part. I shall merely try to point out some of the ways in which climatic pulsations may have exercised a certain

amount of influence upon some of the important events of history. I shall speak chiefly of the possible results of increasing rather than of decreasing aridity, partly because they are more manifest, and partly for lack of space. I shall assume, furthermore, that even where events in Asia are under discussion the climatic curve of California, based on the exact tree measurements, represents the truth more closely than does the largely inferential Asiatic curve. I realize that the considerations which I shall present may seem highly theoretical, but in the early stages of every great scientific problem nothing is so stimulative of thought as a theory to be attacked or defended. The theory, as stated on page 251 of *Palestine and its Transformation,* is as follows: "It seems to be true, as a principle, that, in the regions occupied by the ancient empires of Eurasia and northern Africa, unfavorable changes of climate have been the cause of depopulation, war, migration, the overthrow of dynasties, and the decay of civilization; while favorable changes have made it possible for nations to expand, grow strong, and develop the arts and sciences."

The first and most obvious effects of climatic changes are economic. At the present time countries like Greece and Asia Minor suffer grievously from the failure of crops every few years. There is no reason to think that there has been any distinct change of climate during the past century, and conditions are now probably better if anything than in the early part of the nineteenth century. Nevertheless distress and famine have prevailed more than once, and have been serious contributory causes toward political discontent. If a country like Greece were fully populated about 400 B. C. at the end of two centuries of increasingly favorable climatic conditions, a change such as that which appears to have taken place during the succeeding two hundred years might not cause famines, but it would entail a constant pressure upon the means of subsistence. A highly developed people might thrive and prosper even in the face of growingly adverse conditions and might even be stimulated thereby to greater exertions. Nevertheless the constant pressure of diminishing crops would tend to drive people to emigrate and in the end it might have much to do with weakening them and preparing them for final conquest by outsiders. It would also gradually diminish their purchasing power so that trade would on the whole tend to decline or would seek new channels. The purchasing power of any nation depends ultimately upon the natural resources of the country, and in the case of practically all the nations of antiquity the resources were almost wholly agricultural. Thus a gradual diminution of the crops

would inevitably prevent the growth of trade with foreign countries, and would eventually tend to destroy it. Increasing rainfall would naturally produce the opposite results. To judge from the inscriptions and monuments, trade between Egypt and Mesopotamia was never brisker than in the seventh century before Christ when Assyria was at the height of its power. Again in the period of Rome's chief expansion, not far from the time of Christ, caravan traffic seems to have been carried on in the dry parts of Asia with a vigor far in excess of that which prevailed a few hundred years later. Other conditions may have had much to do with this, but a long succession of good crops could scarcely fail to produce a stimulating effect.

Another result of changes in rainfall and hence in agricultural prosperity would be the effect on the relation of the farming population to the government. If the scale of taxation were based on a period of prosperity, a change to worse conditions would inevitably cause friction. The governors would insist upon the payment of as heavy taxes as formerly; the farmers would declare themselves unable to pay so much. Then, as has happened frequently in Turkey during recent periods of drought, the officials and their minions would make attempts to collect what they considered their due, and would employ force and extortion. Such practices would have the effect which we constantly see at the present time among the Kurds and Armenians. Those parts of the population which did not belong to the governing class would be embittered, and would be ready to listen to anyone who promised them better conditions. It seems probable that many civil commotions and many attempts of usurpers to gain dominion may have been rendered possible by the discontent into which prolonged periods of poor crops have thrown the populace. Here, as in so many cases, physical conditions alone might have little effect, but when combined with the necessary human quality, such as ambition on the part of some petty sovereign, they may have large results. If the people were thoroughly contented, the ambitions of the upstart might never have the opportunity to come to fruition.

Discontent due to prolonged poor crops tends to make people unstable, not only politically but in other ways. Religious bitterness is almost sure to increase under such conditions. A portion of the community attributes its poverty to the fact that its own gods are not so strong as other gods, or that there is something wrong with the present form of religion. The rest of the community is inclined to attribute its distress to the wickedness of its neighbors who decry the old religion; and thus bitterness and persecution are apt to be

engendered. Those who become discontented with the old religion are more than usually ready to accept any new idea which some religious enthusiast may propose. This seems to have been the case when Mohammed came upon the scene of action after the prolonged period of increasing aridity which culminated with a sudden access of dryness in the first half of the seventh century. Without the genius of Mohammed that long period of adversity might have come to an end without any serious upsetting of the old conditions; but on the other hand, without the discontent and unrest fostered by years of distress Mohammed might have appealed in vain, for he would have had to speak to men who did not desire change instead of to those who ardently longed for it.

Thus far we have spoken of internal conditions which would make for the downfall of nations under growingly adverse physical conditions. External conditions would be equally unfavorable. When discord arises between nations it is far more likely to lead to war if the people of one and still more of both countries are discontented. And more than this, foreign invasion may often arise simply because the rulers feel that the best way to avoid trouble at home is to lead their discontented subjects against an enemy. In the case of nomadic tribes such as those of the vast regions of central Asia a period of prolonged aridity brings many of them face to face with the alternative of absolute starvation or migration. There is no question as to which will be chosen by a people who are constantly in motion. When they wander beyond their own territories into those of their neighbors, where also distress probably prevails even if not to so great a degree, fighting inevitably ensues. There is not grass and water enough for all, and someone must move on. Each onward movement brings the migrating bands into conflict with new tribes, and a movement once started may persist for a generation or two, and may be felt across a continent, thousands of miles from the home of the tribe which first moved. Such seems to have been the genesis of many of the great migrations which finally overwhelmed both Greece and Rome. Possibly and indeed probably a certain number of migrations of this sort might have occurred had there been no changes of climate, for the mere pressure of increasing population would sometimes start them, but that they would have been so severe or prolonged as they were seems hardly probable. A steady decline in the areas available for pasturage and in the amount of grass even in the areas where flocks could still be supported must have been a terrible incentive to migration, especially when it lasted five or six centuries, from the time of Christ to that

of Mohammed. In the diagram, to be sure, the decrease in rainfall does not appear to have been so great as in the period from 400 to 200 B. C., but this is largely due to the relatively small number of trees upon which the curve of the earlier period is based, and to the consequent exaggeration of that portion.

At a later time two other events similar to the great barbarian invasions took place, although their duration was by no means so prolonged. In these, according to available evidence, the elements of human ambition and human greatness appear to have figured more prominently than in the earlier barbarian migrations. From about 1000 A. D. to 1200 A. D. the climate of central Asia and of the rest of the world in the same latitude seems to have grown steadily drier. Once again distress and discontent must have reigned among the tents of Central Asia. Here, as in the days of Mohammed, no great concerted movement might have arisen, had it not been for the ambitions of one man. Genghis Khan may have been no more ambitious and no abler than other gifted men of his race, but he happened to live at a time when his people had been brought by nature to a condition of discontent favorable to his aspirations. Therefore, it would seem, he was able in a few years to arouse all the tribes of the steppes and deserts, and sweep over Asia with an almost unparalleled devastation. A century and a half later, in the last quarter of the fourteenth century, another ambitious Asiatic, Timour the Lame, arose, and emulated Genghis Khan. In Timour's case, also, physical conditions seem to have favored his projects, for after half a century of greatly improved conditions, a rather rapid decrease in rainfall took place just at the time when he began his conquests. How much this had to do with the matter I do not attempt to determine, but it should at least be carefully considered before any conclusions are drawn as to Timour and his conquests. Not much later, and in this same period of increasing aridity, the Turks advanced from their dry place of sojourn in the arid centre of Asia Minor and overwhelmed the last shattered remnants of the Byzantine Empire.

The portion of the history of the Roman Empire which centres around the Augustan Age stands in marked contrast to the periods which we have just been discussing. The Californian curve indicates a period of favorable climatic conditions from about 100 B. C. to 75 A. D. Even the low point at the birth of Christ is high compared with the centuries which precede and follow this period of prosperity. During these two hundred years the wars of Rome were very different in character from those which prevailed both before

and after. No great rivals like Carthage threatened the very existence of Rome; nor did rude barbarians like the Goths of later days pour in across her frontiers. She fought to extend her boundaries, her ambitious citizens engaged in battle with one another for the sake of personal ambition, and she quarrelled somewhat with Parthia, a state which met her on terms almost of equality so far as the relative positions of the two were concerned in Asia. In a word the wars of this period were of the kind that are characteristic of prosperity, and were not at all of the devastating kind which arise when the inhabitants of semi-arid regions migrate or plunder because of the impossibility of living at home. Similar conditions prevailed six or seven hundred years earlier when Assyria was at the height of her power and fought to expand her boundaries. In her case, however, the era of prosperity and freedom from harassing invasions was by no means so long as in that of Rome.

It is not possible to go through the course of history and pick out all the cases where prosperity due to favorable climatic conditions may have influenced the political fortunes of a nation, but it would be a most profitable exercise. Often, unquestionably, the influence of favorable climatic environment may have been completely nullified by political causes, or by personal ambitions, or other purely historical considerations, such as the discovery of a new art like the manufacture of iron, or of a new country such as America. Therefore, even if the theory here set forth contains large elements of truth, it is not to be expected that climatic pulsations should invariably be accompanied by the political and social results which would be expected if these physical matters were the only ones concerned in history. Nevertheless it is probable that their influence can be traced in scores of places where hitherto it has been unsuspected.

From great wars and movements of the nations let us turn back to internal affairs, and see how a change of climate in the direction of aridity would affect the composition of a race in its own home. The chief effects would come through disease. Probably insidious diseases such as malaria, consumption, neurasthenia, and the like are the most important sifters of the wheat from the chaff in the physical make-up of a nation, but great epidemics are much more startling and more easily studied. In the case of the plague there is possibly some connection between the times of its occurrence and the times of increasing aridity. As yet the question has never been worked out, and I mention the matter here not as something in regard to which we have any certain knowledge, but merely as an illustration of the interesting type of problems which confront the stu-

dent who chooses to investigate the relation of human history to changes in man's physical surroundings.

It is sufficient here to call attention to the two worst instances of plague that have ever been recorded in history. The first is defined by the *Encyclopædia Britannica* as "the great cycle of pestilence, accompanied by extraordinary natural phenomena, which lasted fifty years [542–592 A. D.], and is described with a singular misunderstanding of medical terms by Gibbon in his forty-third chapter". A reference to the Californian curve shows that this occurred near the end of the long and terrible period of increasing desiccation which began, mildly no doubt, in the first century after Christ, and which during its long centuries may possibly have played so large a part in driving the barbarians into Europe, and in preparing the way for the Prophet of Islam. The seventh century, as well as the latter half of the sixth, was also a time of severe plagues, and this, to judge from our curve, appears to have been the driest and hence most famine-stricken period during three thousand years. After this, when the climate ceased to deteriorate and began to improve, the plague seems to have been somewhat assuaged.

The next of the really terrible plagues was that known as the Black Death. This reached southern Europe in 1346 or 1347 A. D., after having scourged Asia for an unknown period. Even in these modern days of rapid travel an appreciable number of years elapse before the plague can travel across a continent, and in earlier days when communication was far slower, the movement must have been much less rapid. For instance, in 1798 plague prevailed in Georgia and the Caucasus, where it continued to be more or less prevalent until 1819 or later. Meanwhile it spread to Baghdad in 1801, to Armenia and Constantinople in 1802, to Astrakhan in 1805 or thereabout, to Smyrna and Constantinople once more in 1808 and 1809, to Bucharest by land and Malta by sea in 1813, and finally to Dalmatia and the northeastern coast of Italy in 1815. If the spread of this plague from the eastern end of the Black Sea to the northern end of the Adriatic required seventeen years, during a period of relatively active communication, the spread of an earlier plague across the unfrequented deserts of Asia and across two or three times as great a distance would presumably require half a century. Therefore we seem to be justified in framing the working hypothesis that the Black Death may have originated during the famines which in some of the drier parts of Asia must have accompanied the period of aridity lasting from 1100 A. D. to the end of the thirteenth century. In the curve derived from the trees of California it will be

seen that the dry period does not end until 1300. From that time until the appearance of the plague in southern Europe is only forty-six years.

The plague is not the only disease which may have been influenced by changes of climate. Malaria, although far less fatal than the plague, is far more dangerous in its ultimate effects. The plague passes over the land and is gone; the dead are dead, and the living have suffered no serious injury. Malaria, on the contrary, hangs on year after year, not killing its victims, but sapping their energy and vitality. The presence and the abundance of malaria are closely associated with climate and topography. Without entering into any discussion of the origin of malaria, let me point out how a change toward aridity in a country like Greece and, to a less extent, Italy, would probably foster the disease.

Malaria is pre-eminently a disease of tropical and subtropical countries whose climate is characterized by alternate wet and dry seasons. Except in the perennially moist portions of the tropics, the streams of such regions are subject to seasonal floods which spread over wide areas for a short period and then disappear, leaving innumerable stagnant pools and swamps, ideal breeding places for the anopheles mosquito. Permanent bodies of water usually contain fish which eat the mosquito larvae and reduce their numbers, or else the water moves sufficiently to carry away most of the eggs that are laid in it. When the climate of a subtropical country becomes drier, the conditions which favor the mosquito are intensified. This comes primarily from the death of vegetation upon the mountains. The scarcity of vegetation allows the soil which had formerly been held in place by roots and by the cover of dead leaves to be washed rapidly away. The streams are thereby overloaded and begin to fill their valleys with sand and gravel, while the flowing water is forced to wander hither and thither over broad flood plains in innumerable channels, which form pools when the floods are assuaged, or else the water loses itself in marginal swamps. The streams also become intermittent and no longer contain large quantities of fish. Thus everything co-operates to reduce the number of streams which flow steadily throughout the year and to increase the number of bodies of stagnant water in which the mosquitoes may live. This in itself may produce most widespread effects. How great they are may be judged from the success of the United States government in eradicating malaria at Panama by the opposite process of reducing the number of places where mosquitoes can breed.

At the present time malaria is endemic in Greece and Rome. That is, it is always there, and is looked upon as one of the necessary diseases of childhood, much as we look upon the measles. Sir Ronald Ross of the Liverpool School of Tropical Medicine is responsible for the statement that nearly half the people of Greece have suffered genuine injury from malaria, and in Italy the case is scarcely better. Up to the age of puberty children are attacked by it every autumn. They grow weak and sallow, their spleens are permanently enlarged, and their vitality is lowered for life. No one who has suffered from malaria will question the severity of its results and the length of time which elapses before they are eradicated even in the case of adults. In spite of quinine, which has come to our aid in modern days, it is one of the most insidious of diseases. Every traveller who has seen much of the Orient knows how the sufferers from malaria lie and groan for days, and later have no energy for months, but go languidly to the necessary tasks, and as soon as possible sit down to rest with open, stupid mouths. Physicians agree that it is impossible to expect much initiative or energy from a nation in which for centuries almost half of every generation has been devitalized by this baneful disease.

From a painstaking study of classical authors Mr. W. H. S. Jones has concluded that up to about 400 B. C. in Greece and 200 B. C. in Rome, malaria was almost unknown.[5] Then it appeared, and during the succeeding century or two became common. At first it attacked adults, which shows that it was a relatively new disease, which was still epidemic and not endemic, or else, we would add, that Greece was on the very border of its habitat. Later it became permanently located in the respective countries and attacked chiefly children, the older people having become immune after suffering in childhood. It is noticeable that the introduction of malaria coincides with the beginning of the weakening of Greece and Rome, and the time when it became endemic, in Greece at least, is synchronous with the epoch when the lustre of the ancient names became irretrievably dimmed.

Ross and Jones are of the opinion that, along with various other factors, malaria was one of the important causes of the fall of Greece and Rome. The growing effeminacy and lightness of the Greeks and the brutality of the Romans, are just the effects which they think would be produced upon people of the respective temperaments of the two races. The case is so strong that one can scarcely resist the conclusion that this pathological factor may have

[5] W. H. S. Jones, *Malaria: a Neglected Factor in the History of Greece and Rome* (Cambridge, England, 1907).

played an important part in the psychological changes which appear to have accompanied the decline of civilization and of population in both Greece and Rome. In the present state of knowledge it would be rash to assert that the increase in the amount and severity of malaria was due to climatic changes. Other influences, such as contact with Egypt and the introduction of slaves, may have been equally effective. Nevertheless it is noteworthy that the spread of the disease in both Greece and Rome seems to have proceeded most rapidly during and after the time when a change of climate appears to have rendered the topography of the valleys and the behavior of the streams more favorable than hitherto to the propagation of the anopheles mosquito.

In conclusion let me call attention to one more way in which the change from relatively moist, stormy, cool conditions to those of aridity may have affected the Greek, Roman, and other races. In the opinion of many scholars one of the most important factors in the greatness of these powers was the presence of a race of northern invaders. Take the case of Greece. These northern Achaeans came into the country about 1200 B. C. and their coming may have had some connection with the dry period of which we find evidence both in America and Asia. After their arrival the climate on the whole, although with some fluctuations, appears to have become more propitious, so far as our meagre data afford any indications. Up to the middle of the third century it continued to be favorable. Then it became more arid. It is well known that races are very sensitive to climatic environment. The negro would apparently die out in the northern United States were he not replenished from the South. The Scandinavian does not seem to prosper greatly in the dry, sunny portions of the United States; he is there subject to diseases of the skin and nerves which appear seriously to deplete his numbers in a few generations; whereas in the rainy northwest, which resembles his native habitat, he thrives greatly both in body and estate. It may have been the same with the northern invaders in Greece. So long as the climate was propitious they flourished and lent strength to the country. Then, when conditions became less favorable, the unseen ravages of malaria and other diseases may have attacked them with especial severity, so that in the course of centuries they gradually disappeared, thus weakening the Greek people to so great a degree that there has been no recovery.

It would be possible to go on with other and equally important ways in which changes of climate may perhaps have co-operated with other factors in causing the decline of nations, or in stimulating

them at times when the changes were favorable. We must leave the matter here, however, with the hope that it may be investigated more thoroughly by historians, who alone possess the necessary information to carry the matter to its full conclusion. Enough has been said to show, in the first place, that the theory of pulsatory changes of climate appears to be firmly grounded. The conclusions here presented as to the dates and degree of changes may be modified, but the general conclusion does not seem likely to be upset. In the second place we have shown that there are many and important ways in which it is possible that climatic pulsations, directly or indirectly, may have modified the course of history. Only when their true effect is thoroughly understood shall we be sure that we are rightly estimating the importance of the other factors with which they combine to produce the complex results of history.

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